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NORTHERN VIGOUR OF STRAWBERRY CROWNS: ADDRESSING COMMERCIAL DEVELOPMENT NEEDS

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Northern Vigour of Strawberry Crowns: Addressing Commercial Development Needs

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Abstract

The overall objective of this project is to further the development and commercialization of strawberry plants (crowns) in Saskatchewan. To accomplish this, several issues were addressed: a) nematode testing; b) postharvest handling; c) micropropagation. This represents the final report of this project. Specifically, the study: A) developed nematode testing capabilities at the provincial government Crop Protection Lab in Regina (Grant Holzgang, manager). It also conducted an evaluation of current nematode levels in Saskatchewan soils and crowns. B) Identified postharvest handling and storage methods which would optimize productivity and C) Scoped out cost of micropropagation and developing parent material in Saskatchewan.

A nematode testing facility has now been established at the Regina Crop Protection Lab in conjunction with Dr. John Chitambar, Chief Nematologist, California State Agriculture who was brought into Saskatchewan to help set up the lab. Grant Holzgang was also sent down to Dr. Chitambar's lab for further training. This facility is specialized to evaluate nematodes of importance in strawberry crowns but can also be expanded to examine other species. The positive test of *Aphelenchoides fragariae* on the California-grown crowns in 2002 was of concern since Saskatchewan fruit growers import a large number of crowns from California and may be infecting Saskatchewan fields. Furthermore, a test of root zone and crowns of native strawberry plants found no nematodes present. Nematode testing on crown samples from the same California strawberry crown propagator in the spring of 2003 resulted in no *Aphelenchoides fragariae* detected. Nematode testing of Saskatchewan-grown greenhouse plug plants also found no nematodes in crown tissue.

Harvest date, time in field and time of processing were all significant. Harvesting on the later date of October 10th when mean day temperature was 5°C produced the highest flower yield. Leaving the crowns after harvest in the cooler at 4°C for 3 weeks negatively impacted flower number over a 4 month greenhouse growth period at both harvest dates. Initial processing time of 48 h at 23°C positively increased most parameters measured at the end of the 4 month greenhouse period except root dry weight.

Cost of micropropagation is not an issue. Plantlets are available and can be easily micropropagated. The licensing of a laboratory in Saskatchewan to produce nuclear Californian stock may be an issue and will have to be discussed directly with the University of California, which holds the royalties on 'Camarosa'. Dr. Bob Bors (University of Saskatchewan) is developing advanced selections of strawberry plants which growers in California are willing to test. In the long term, Saskatchewan should develop its own varieties for California in order to maintain control and revenue over this portion of the production system.

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1.0 Introduction

There is a large market for strawberry crowns in California, Florida and other areas in Canada and internationally. California uses approximately 700 million strawberry crowns each year, all of which are grown in northern California and Oregon. The value of these crowns is over $40 million U.S. or $60 million Cdn. The second largest market is Florida which annually plants 112 million strawberry crowns with a value of about $ 7 million U.S. or over $10 million Cdn. In contrast to California, approximately 90% of Florida's crowns come from Canada (Nova Scotia, Quebec and Ontario). The Florida case demonstrates the feasibility for Canadian nurseries to capture the U.S. demand for strawberry plants. The eastern provinces were successful largely because they could produce disease-free plants and partly because of their cooler climate. Saskatchewan has even greater advantages when it comes to climate and the Northern Vigour® effect. California growers are particularly interested in Saskatchewan because unlike propagators elsewhere, we do not require the fumigant, methyl bromide, to produce our crowns. This fumigant will be de-licensed after 2005 and therefore cannot be used at all after this date.

1.1 Nematode Testing

Export to the U.S. of ANY crop requires certification that the shipment is free from nematodes. Export into California has 3 levels to overcome (federal, state and county). The USDA has a list of nematodes in A, B, C, and D categories which are of varying importance with A and B being of highest economic importance (see Appendix 1 attached). Nematodes of these 2 categories will not be permitted into the California County. Strawberry crown and fruit production land is normally fumigated to destroy weeds, diseases and nematodes. Nematodes in Saskatchewan are generally not perceived to be a problem by buyers in California due to our cold winters. While the general consensus is that Saskatchewan is free of nematodes, this concept is not correct. Nematodes are present but they are in the C and D categories and thus are allowed into California (Appendix 2). However, continuous monitoring with each shipment is required. There are no nematode testing facilities in Western Canada. Currently, the University of Guelph is the only location but it does not identify nematodes down to the species level which is required by California. Deterioration of nematodes on plant material in transit to Guelph is another concern as well as the $80.00 per plant sample. Since a Provincial Crop Protection Lab (CPL) already exists in Regina for commercial growers, it makes sense to further develop and expand that unit. Grant Holzgang is the manager of that facility. They have the equipment necessary for nematode testing (see equipment and supplies list, Appendix 3). In addition, Mr. Holzgang has some background in nematology but can update his knowledge with annual courses currently conducted at the University of California, Riverside (Appendix 4). Since we are trying to meet California's requirements, it also makes sense to ensure our provincial testing facilities are approved by them. Dr. Chitambar, Chief Nematologist in California agreed to fly to Saskatchewan for this purpose. He has already provided his requirements for equipment and supplies (Appendix 3). Dr. John Potter, Chief Nematologist, Agriculture Canada in Vineland has also independently provided a list (Appendix 5) with suggestions.

There has been no systematic nematode testing in Saskatchewan soils to date. Nematode testing will be required in future if root crops, including medicinal plants will be exported to the U.S. Thus, this expanded lab may provide a service to several industries.

1.2 Postharvest Handling

Plants shipped in October, 2000 had losses of 15 to 40%. Losses beyond 5% are considered significant. The problem was thought to be a combination of frost damage, length of storage and shipment, and method of boxing. Optimizing procedures of postharvest handling are required. The methods used were based on the practices in Atlantic Canada and shipment of small quantities of research-level plants to California. If the strawberry crown industry is to develop in this province, growers will need to know: a) environmental conditions to harvest; b) length of time at warm temperature crowns can be handled in the field before reducing yield; c) length of time crowns can be cut, trimmed and stored before significant reduction in yield and growth.

1.3 Micropropagation and development of new strawberry cultivars

This section addresses the issue of where Saskatchewan nurseries will acquire their planting material in future. The current cultivar, 'Camarosa' was developed by the University of California at Davis. That institution holds the royalties for this cultivar. The source of the registered planting material for Saskatchewan growers comes from California-based nursery propagators such as Norcal or Lassen Canyon. Saskatchewan growers need to plant registered-level material in order to subsequently sell the next generation (certified-level) to California fruit growers. This dependency on the California nurseries is not a good situation in that both are in competition for the same market. The alternative is to propagate parent material in Saskatchewan through tissue culture and screening. Procedures and costs need to be scoped out. A new faculty member in the Dept. of Plant Sciences, Dr. Bob Bors, is a strawberry breeder and development of new cultivars may be more feasible in the future. Alternatives such as encouragement of California propagators to partner with Saskatchewan growers will also be explored.

2 Materials and Methods

2.1 Nematode Lab and Testing

From January 8-15, 2002, Grant Holzgang (Regina Crop Protection Lab) was sent to Dr. Chitambar's lab in California to learn techniques and procedure of nematode extraction and identification based on California standards. Dr. Chitambar visited the University of Saskatchewan and Regina Crop Protection lab between July 6-10, 2002. He discussed California procedures and practices for nematode testing. In May 2002, 'Camarosa' crowns received from 'Norcal' nurseries were evaluated for presence of pathogenic nematodes. One sample of 25 crowns was sent to the CPL. The remaining crowns were distributed to cooperators in Saskatchewan. Cooperators included: Brenda and Loren Lange, Meadowlake; Janine Kopanko-Kerber, Seager Wheeler Farm, Rosthern; Bill and Jean King, Outlook; Rod and Hazel Peterson, Love; and Rod and Jean Flaman, Edenwold. About 250 'Camarosa' plants were distributed to each cooperator.

Soil sampling for nematode levels were performed just prior to planting. 'Camarosa' crowns were also planted in late May in the Agriculture Greenhouses, University of Saskatchewan. Mother and new daughter plants were sampled for nematode presence on July 8, 2002. Native strawberry crowns were also sampled from 2 locations in Saskatchewan: a) 20 km north of Lipton, SK (1.25 km to the east of highway #35) from farmland with sandy soil; b) 10 km north east of Quill Lake, black clay loam soil.

The precise methodology according to California standards are kept at the Crop Protection Lab, Regina. Photographs of portions of the method are shown below (Figs. 1-9).

2.2 Postharvest Storage and Handling

Superficially, since Ontario and Nova Scotia currently ship crowns, it might appear that direct technology transfer is simply required without further research. However, Ontario and Nova Scotia shipping practices (and therefore postharvest requirements) are very different from Saskatchewan. Ontario and Nova Scotia have trucks continuously travelling down to Florida in peak season.

Saskatchewan's commercial industry is not presently sufficiently large enough to process, load and send trucks down to California on a daily basis. Growers are expected to be located throughout the province and trucks will need to travel around to pick up harvests from several processing centers. Therefore, crowns will be held in storage for longer periods of time before shipping down to California. Common sense practices such as removal of field heat as quickly as possible, avoidance of dehydration stress, and maintaining the crowns at low temperatures are obvious. However, the question of how long crowns can be stored and through what economic means should be addressed. Several small factorial experiments were designed to test the interaction between temperature and time.

Strawberry crowns from the 2000 commercial venture which were leftover in the field in 2001 were utilized. Plants were staggered in harvest (2 harvest dates: October 3 (13°C and October 10 at 5°C representing mean field temperatures during the period of harvest), left in the field for 0, 2 and 4 hrs before transporting to the trimming shed and subsequently sub-sampled from each of these 3 treatments and left at 4 length of processing treatment conditions: 0, 24, 48 hrs at 23°C and 24 hrs at 23°C followed by 3 weeks at 4°C. These latter 4 treatments were intended to simulate the length of time of processing before crowns may be placed into a reefer truck if small crown producers do not have easy access to cold storage or many skilled workers. The 3 weeks at 4°C simulated length of time in storage after trimming and worst case scenarios of trucking. Crown fresh and dry weights were taken at the end of each treatment. Ten replications were used for each treatment.

Crowns from all treatments were then grown in the greenhouse (16 hr, 23/15°C), approximately 450 PAR and examined for date of flowering, flower number, leaf number, leaf and root dry weight on a weekly basis for a period 18 weeks after sampling. These greenhouse observations were intended to simulate California conditions and provide an indication of the impact of these postharvest treatments on subsequent growth and yield of the crowns. Twenty replications were used for these each of these treatments. Experiments were analyzed as a three factor factorial, cross-classified. The factors were: harvest date, time in field and time for processing.

3 Results
3.2 Nematode lab and testing

Grant Holzgang was sent to California from January 8 to 15, 2002 for training in Dr. John Chitambar's laboratory. Training included: extraction procedures, extraction media, identification of different genera and species were of concern on strawberries (e.g. *Aphelenchoides*, *Pratylenchus*, *Criconemella*, *Ditylenchus*, etc.). The facilities at the Crop Protection Lab in Regina were subsequently expanded and funding from this project was used to purchase the necessary equipment and supplies.

Dr. Chitambar was invited to the University of Saskatchewan and to the Regina Crop Protection laboratory. Dr. Chitambar arrived in Saskatoon on July 6, 2002 and departed Regina on July 10, 2002. While in Saskatoon, he toured the university and Karen Tanino hosted a supper at her home with the following people in attendance: Dr. Jill Thomson (pathologist, Dept. Plant Sciences), Dr. Manjula Bandara (Senior research scientist, special crops), Tom Ward (fruit specialist), Dr. Bob Bors (strawberry breeder, Dept. Plant Sciences), and James Lokken (Agriculture economist who worked on strawberry crown marketing studies). Mother crown and daughter samples from the College of Agriculture greenhouses were taken. Drs. Chitambar and Tanino drove down to Regina. Enroute, they stopped into one of the cooperator's sites in Outlook, SK (Bill and Jean King). Soil and crown samples were taken from this location. Dr. Chitambar provided guidance in terms of the depth of sampling. Sampling was conducted down to 4 inches with a hand trowel. Dr. Chitambar inspected the Regina lab and suggested the lab acquire a different type of dissecting microscope with a mirror attachment for bottom light. Temperature of water for extraction was suggested to be increased. He also offered to examine samples difficult to identify or provide a second opinion if the Regina lab could send digital images through the computer. Since that time, water temperature has been addressed (water is now re-circulated), Dr. Tanino has provided the necessary dissecting microscope and is in the process of acquiring a Zeiss microscope adapter and a digital camera. Dr. Chitambar indicated the Regina lab should now be at the level capable of nematode speciation.

It was both surprising and of concern that 'Camarosa' crowns purchased from California tested positive for *Aphelenchoides fragariae*, strawberry crimp nematodes (Table 3.1). This was based on one sampling of 25 crowns from one supplier. In 2003, a wider range of suppliers and multiple samplings are intended to determine if this test is consistent. A portion of these crowns were subsequently planted under greenhouse conditions and sampled 2 months later on both original mother crown and newly produced daughter crown material. The soilless mix potting soil in which the crowns were growing was also sampled. All of these samples tested negative and provide additional support for the value of greenhouse-grown plug plants.

Three out of the five sites tested positive for *Aphelenchoides fragariae* (Table 3.1). Sites which were previously grown to strawberry production tested both positively (Outlook, SK) and negatively (Meadowlake, SK) for this nematode. Thus, it is difficult to determine the origin of the nematodes at these locations. Native strawberry crowns were sampled at 2 locations in Saskatchewan and both sites tested negative. These studies should be expanded in future with more baseline data accumulated.

Subsequent crown tests in 2003 of imported material from 'Norcal Nurseries' in California revealed no *Aphelenchoides fragariae*. Greenhouse-grown plug plants from Floral Acres (Kelvin Mah) also tested negative for any nematodes in 2003.

3.2 Postharvest Storage and Handling

3.2.1 Date of harvest

Date of harvest was highly significant (Tables 3.2, 3.3). Harvest on October 3rd which corresponded to a higher mean day field temperature of 13°C, significantly reduced crown fresh weight by almost 2 grams per crown. This represents an approximate 20% reduction in fresh weight depending on the time of harvest. The dry weight was also higher on the October 10th sampling date. The October 10th field temperature was only 5°C. While these responses may initially appear to be related to harvest temperature, percentage crown water content was not significantly different between harvest dates. Thus, the lower crown fresh weight on October 3rd may be more related to smaller crowns and by the October 10th sampling date, the crowns had grown larger. None of the other treatments (time in field, time of processing) were significant (Table 3.3).

Date of harvest significantly affected flower number and root fresh weight, taken at the end of four months of greenhouse growth (Table 3.4). On average, the October 10th harvest date produced 2.5 more flowers than the October 3rd date (Table 3.5). Whether this response is due to reduced stress of the October 10th harvest date or to additional chilling hours is not clear. Root fresh weight of the October 3rd sampling date was significantly greater than the October 10th sample.

3.3.1 October 3 harvest date, effect of time in field and time in processing

The delay in time in the field after harvest from 0, 2 to 4 hours at 13°C on October 3rd affected flower number, leaf dry weight as well as root fresh and dry weights after 4 months growth under greenhouse conditions (Tables 3.5, 3.7).

Surprisingly, the delay in the field increased flower number with the highest flower number produced under a 4 hour delay in the field. Leaf dry weight was also higher under the 2 hour field delay with a significant interaction with time in processing. The longer the time in processing in the 2 hour field delay, the greater the leaf dry weight. However, this response did not hold for the 0 and 4 hour field delay (Table 3.7). The longest time in processing (24 hours at 23°C followed by 3 weeks at 4°C) reduced flower number by the greatest degree (Tables. 3.6, 3.7). Root fresh and dry weights were significantly negatively impacted by both time in the field and time in processing with a significant interaction (Tables 3.5, 3.6, 3.7). Root fresh and dry weights were reduced with the length of time in the field and processing even after 4 months of greenhouse growth.

3.3.2 October 10 harvest date, effect of time in field and time in processing

Time in the field only had a significant effect on root dry weight on the October 10th field harvest date when the mean temperature was 5°C. Thus, the impact of harvest is evident even after this length of time. Time in processing significantly affected all responses with the interaction with time in field also significant. Surprisingly, all parameters except root dry weight were positively affected by increased length of time in processing with the highest values generally coinciding with the 48 h treatment. Notably, flower number did not increase with the 3wk treatment under 4°C and indicates storage under cool temperatures for prolonged periods to increase flowering is not supported.

3.4 Micropropagation

The University of Saskatchewan (Tanino's program) had 'Camarosa' strawberry crowns in tissue culture. The cost of micropropagation will not be a problem since strawberry are easily micropropagated and the plantlets are available from the University of California. However, whether the University of California will allow licensing to propagate nuclear stock should be examined.

4 Conclusions

A nematode testing facility has now been established at the Regina Crop Protection Lab. This facility is specialized to evaluate nematodes of importance in strawberry crowns but can also be expanded to examine other species. However, purchase of a digital camera and a microscope adapter would greatly enhance capabilities. Dr. Chitambar has offered to diagnose questionable samples and a digital camera is essential to e-mail photos. While the most recent 2003 California crown sample did not produce any nematodes, the positive test of *Aphelenchoides fragariae* on the 2002 California-grown crowns is still of concern since Saskatchewan fruit growers import a large number of crowns from California and may be infecting their fields. The lack of nematodes on greenhouse plug plants shows promise for this type of propagation in future.

Harvest date, time in field and time of processing were all significant. Harvesting on the later date of October 10th when mean day temperature was 5°C produced the highest flower yield. Leaving the crowns after harvest in the cooler at 4°C for 3 weeks negatively impacted flower number over a 4 month greenhouse growth period at both harvest dates. Initial processing time of 48 h at 23°C positively increased most parameters measured at the end of the 4 month greenhouse period except root dry weight.

Micropropagation of strawberry crowns at a commercial rate and value should not be a problem. However, the licensing of Saskatchewan companies to micropropagate strawberry crowns should be investigated directly with the University of California.

Table 3.1 Summary of nematode analysis from the Crop Protection Lab, Regina.

Date	Location	Sample type	Nematode level
Samples received into Crop Protection Lab: June 4, 2002	From 'Norcal' Nurseries, northern California	'Camarosa' strawberry crowns.	*Aphelenchoides fragariae*, strawberry crimp
July 8, 2002	Agriculture greenhouses, University of Saskatchewan	'Camarosa' strawberry crowns from Norcal Nurseries planted under greenhouse conditions in 6" pots in Sunshine Mix #4 in early May, 2002 and sampled in early July, 2002.	No pathogenic nematodes detected
July 8, 2002	Agriculture greenhouses, University of Saskatchewan	'Camarosa' daughters produced from the above crowns under greenhouse conditions.	No pathogenic nematodes detected
July 8, 2002	Agriculture greenhouses, University of Saskatchewan	Sunshine Mix #4 (artificial potting media) from the above pots.	No pathogenic nematodes detected
May 25, 2002	Outlook, SK	Soil (previously in strawberry production)	*Aphelenchoides fragariae*, strawberry crimp
May 29, 2002	Rosthern, SK	Soil (not previously in strawberry production)	*Aphelenchoides fragariae*, strawberry crimp
June 5, 2002	Rosthern, SK	Soil (not previously in strawberry production)	*Aphelenchoides fragariae*, strawberry crimp
May 27, 2002	Love, SK	Soil (previously in strawberry production)	No pathogenic nematodes detected
May 28, 2002	Meadowlake, SK	Soil (previously in strawberry production)	No pathogenic nematodes detected
August 28, 2002	Quill Lake, SK	Native strawberry crowns	No pathogenic nematodes detected
August 28, 2002	Lipton, SK	Native strawberry crowns	No pathogenic nematodes detected
June, 2003	From 'Norcal' Nurseries, northern California	'Camarosa' strawberry crowns.	No pathogenic nematodes detected
September, 2003	Floral Acres, Saskatoon	Greenhouse-grown plug plants	No pathogenic nematodes detected

Table 3.2 Mean crown fresh, dry weights and percentage water content

Harvest date	Time in field (hr)	Time of processing (hr)	Mean Fresh Weight (g)	Mean Dry Weight (g)	Mean % water content
October 3	0	0	5.1	1.9	59.9
	0	24	8.4	2.7	65.2
	0	48	5.9	1.7	70.8
	0	24-3 wks	4.9	1.8	57.5
	2	0	8.1	3.3	57.8
	2	24	10.4	4.1	58.6
	2	48	7.3	2.2	70.3
	2	24-3wks	13.8	2.4	66.3
	4	0	10.7	4.1	61.0
	4	24	8.6	3.6	56.6
	4	48	10.9	3.4	69.1
	4	24-3wks	6.4	2.7	53.4
Total mean			**8.4**	**2.9**	**62.2**
October 10	0	0	9.7	3.5	62.9
	0	24	11.8	3.6	67.2
	0	48	12.3	5.1	52.8
	0	24-3wks	10.0	4.2	56.7
	2	0	10.0	3.5	66.1
	2	24	13.0	4.9	60.4
	2	48	13.0	4.8	62.6
	2	24-3wks	10.8	4.0	61.2
	4	0	8.1	3.0	62.8
	4	24	12.3	3.9	68.3
	4	48	9.5	3.9	59.2
	4	24-3wks	9.0	3.8	58.4
Total mean			**10.5**	**4.0**	**61.6**

Table 3.3 Summary of significance, crown fresh, dry weight and water content

Treatment	Crown Fresh Weight	Crown Dry Weight	Crown percentage Water content
Harvest date	*, P=0.011	**, P=0.000	NS
Time in field	NS	NS	NS
Time of processing	NS	NS	NS

* = significant at 0.05 level; ** = significant at the 0.01 level; NS = Not Significant

Table 3.4 Summary of significance, effect of harvest date

Treatment	Leaf number	Flower Number	Leaf Fresh weight	Leaf Dry weight	Root Fresh weight	Root Dry weight
Harvest date (Oct. 3, 10)	NS, P=0.987	**, P=0.000	NS, P=0.172	NS, P=0.341	**, P=0.007	NS, P=0.922

* = significant at 0.05 level; ** = significant at the 0.01 level; NS = Not Significant

Table 3.5 Summary of final mean leaf and flower numbers; leaf, root fresh and dry weights at the end of 18 weeks of growth under greenhouse conditions.

Harvest date	Time in field (hr)	Time of processing (hr)	Final leaf #	Final flower #	Leaf fresh Wgt. (g)	Leaf Dry Weight (g)	Root fresh Weight (g)	Root Dry Weight (g)
October 3	0	0	16.4	9.4	64.0	16.3	57.7	6.7
	0	24	11.6	9.7	51.0	11.1	22.0	2.4
	0	48	12.4	11.3	55.0	12.9	29.1	3.6
	0	24-3 wks	14.0	5.8	50.2	11.6	22.5	1.5
Mean			13.6	9.0	55.0	13.0	32.8	3.6
	2	0	12.0	11.0	51.2	11.1	28.3	3.7
	2	24	11.9	10.5	53.6	16.6	22.3	3.5
	2	48	15.4	13.4	81.9	17.6	35.5	7.0
	2	24-3wks	18.0	7.7	62.7	21.0	21.2	1.9
Mean			14.3	10.6	62.3	16.5	26.9	4.0
	4	0	13.1	12.4	47.8	10.9	21.3	3.1
	4	24	13.5	15.8	71.0	14.1	34.6	3.9
	4	48	16.1	13.1	71.6	16.4	25.9	3.9
	4	24-3wks	18.3	10.7	71.0	15.4	23.0	12.8
Mean			15.2	13.0	65.2	14.2	26.2	5.9
LSD			**3.66**	**3.13**	**18.96**	**5.91**	**10.9**	**1.61**
October 10	0	0	12.3	10.0	46.1	10.8	16.3	2.5
	0	24	16.2	16.2	81.4	16.6	26.5	3.6
	0	48	12.3	13.8	56.9	13.3	25.4	3.3
	0	24-3wks	16.3	9.7	56.9	14.9	18.0	2.2
Mean			14.3	12.4	60.3	13.9	21.5	2.9
	2	0	14.5	14.1	58.7	12.9	22.3	3.6
	2	24	12.2	16.1	52.9	11.8	21.8	3.5
	2	48	12.4	13.8	68.0	14.7	27.6	3.9
	2	24-3wks	19.1	9.0	61.8	16.8	21.4	4.4
Mean			14.6	13.2	60.4	14.1	23.3	3.9
	4	0	----	----	----	-----	----	-----
	4	24	12.0	15.6	68.2	15.7	23.2	4.0
	4	48	15.8	22.0	91.7	21.4	43.1	5.8
	4	24-3wks	15.0	7.4	57.1	14.2	18.4	2.6
Mean			14.3	15.0	72.3	13.4	28.3	4.1
LSD			**3.78**	**3.44**	**19.46**	**4.72**	**9.08**	**1.46**

LSD=Least Significant Difference at 0.05 level.

Table 3.6 Summary of Time of Processing with responses meaned over time in field.

Harvest date	**Time of processing (hr)**	**Final leaf #**	**Final flower #**	**Leaf fresh Wgt. (g)**	**Leaf Dry Weight (g)**	**Root fresh Weight (g)**	**Root Dry Weight (g)**
October 3	0	13.8	10.9	54.3	12.8	35.8	4.5
	24	12.3	12.0	58.5	14.0	26.3	3.3
	48	14.6	12.6	69.5	15.6	30.2	4.8
	24-3 wks	16.7	8.0	61.2	16.0	22.2	5.4
LSD		**3.7**	**3.1**	**19.0**	**5.9**	**10.9**	**1.6**
October 10	0	13.4	12.0	52.4	8.6	19.3	6.7
	24	13.4	16.0	67.5	14.7	23.8	3.7
	48	13.5	16.5	72.2	16.5	32.0	4.3
	24-3 wks	16.8	8.7	58.6	15.3	19.2	3.1
LSD		**3.8**	**3.4**	**19.5**	**4.72**	**9.1**	**1.5**

Table 3.7 Summary of significance for October 3 harvest, time in field and processing

Treatment	Leaf number	Flower Number	Leaf Fresh weight	Leaf Dry weight	Root Fresh weight	Root Dry weight
Time in field (A)	NS, P=0.207	**, P=0.000	NS, P=0.097	*, P=0.058	*, P=0.033	**, P=0.000
Time in processing (B)	**, P=0.001	**, P=0.000	*, P=0.051	NS, P=0.226	**, P=0.000	**, P=0.000
Interaction A x B	*, P=0.022	NS, P= 0.276	*, P=0.017	*, P=0.032	**, P=0.000	**, P=0.000

* = significant at 0.05 level; ** = significant at the 0.01 level; NS = Not Significant

Table 3.8 Summary of significance for October 10 harvest, time in field and processing

Treatment	Leaf number	Flower Number	Leaf Fresh weight	Leaf Dry weight	Root Fresh weight	Root Dry weight
Time in field (A)	NS	NS	NS	NS	NS	**
Time in processing (B)	*	*	*	**	*	**
Interaction A x B	**	**	**	**	**	**

* = significant at 0.05 level; ** = significant at the 0.01 level; NS = Not Significant

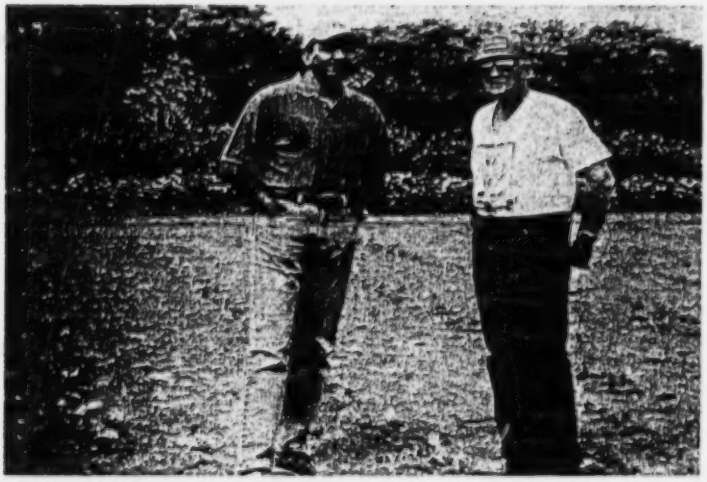
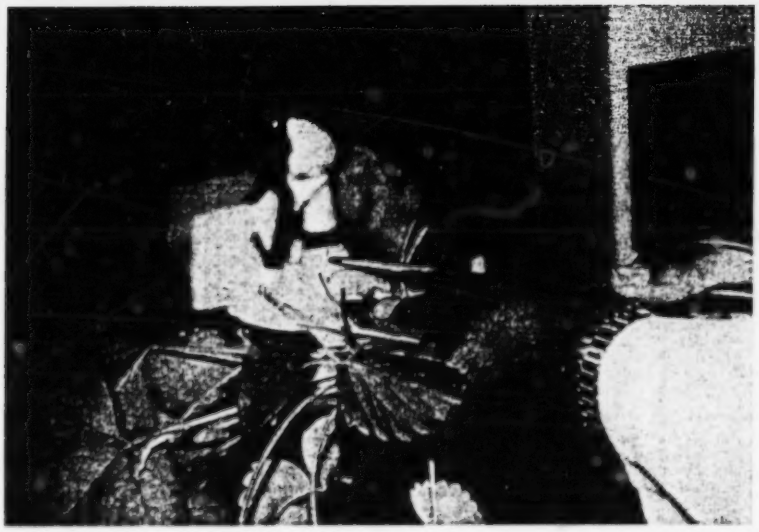


Fig. 1. Upper figure: Dr. Chitambar (seated) at the Crop Protection Lab, Regina with Grant Holzgang (left) and summer research assistant.

Lower figure: Dr. Chitambar (left) with Bill King (strawberry cooperator) on site in Outlook, SK, July, 2002.



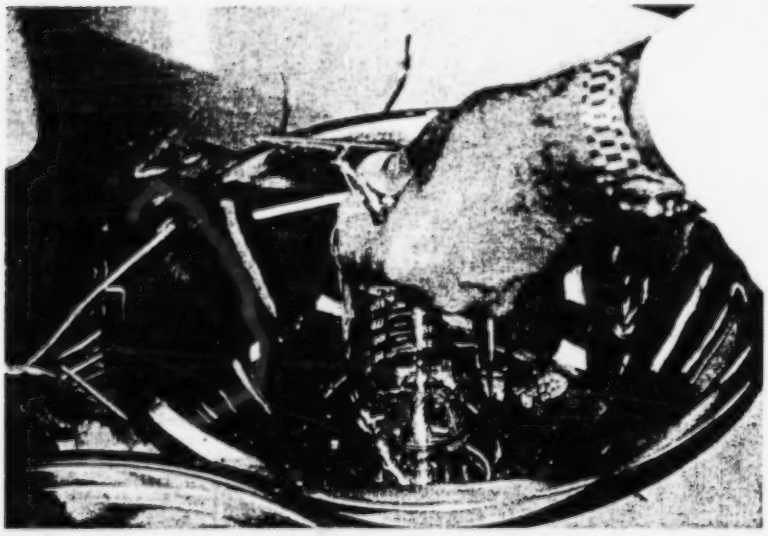


Fig. 2. Upper and lower figures: preparing strawberry crown samples for nematode testing.

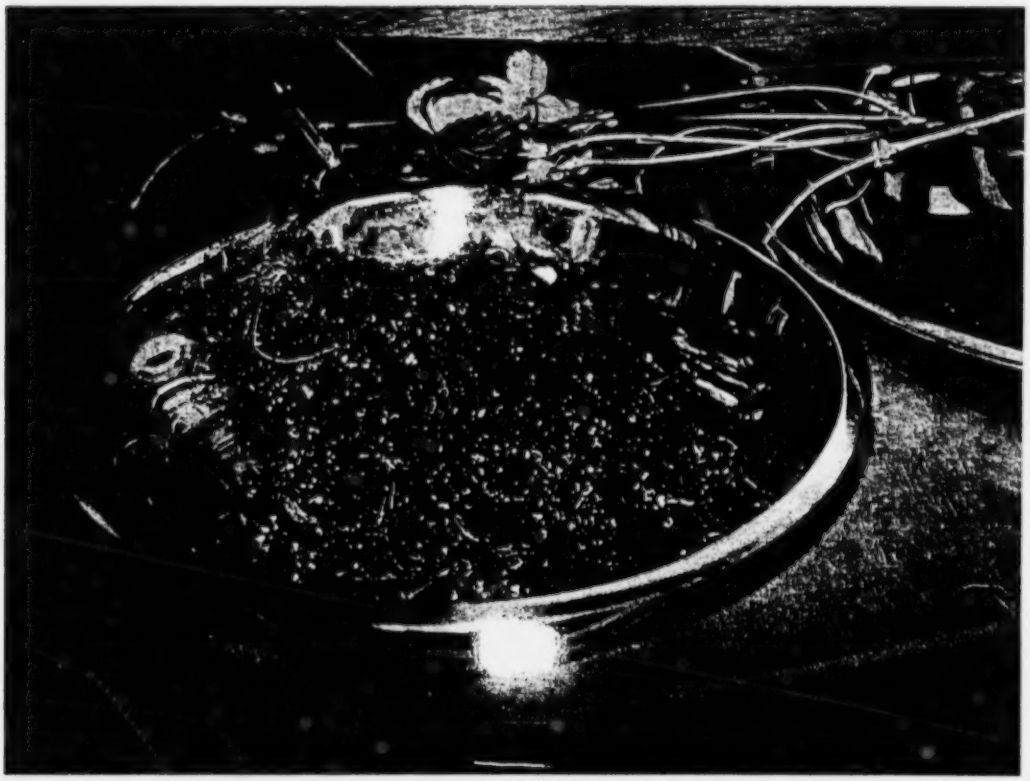


Fig. 3. Upper: sliced strawberry crowns prior to nematode testing. Lower: strawberry roots ready to be washed for nematode testing.

Fig. 4. Washing strawberry crown roots to remove soil. Soil is sieved.

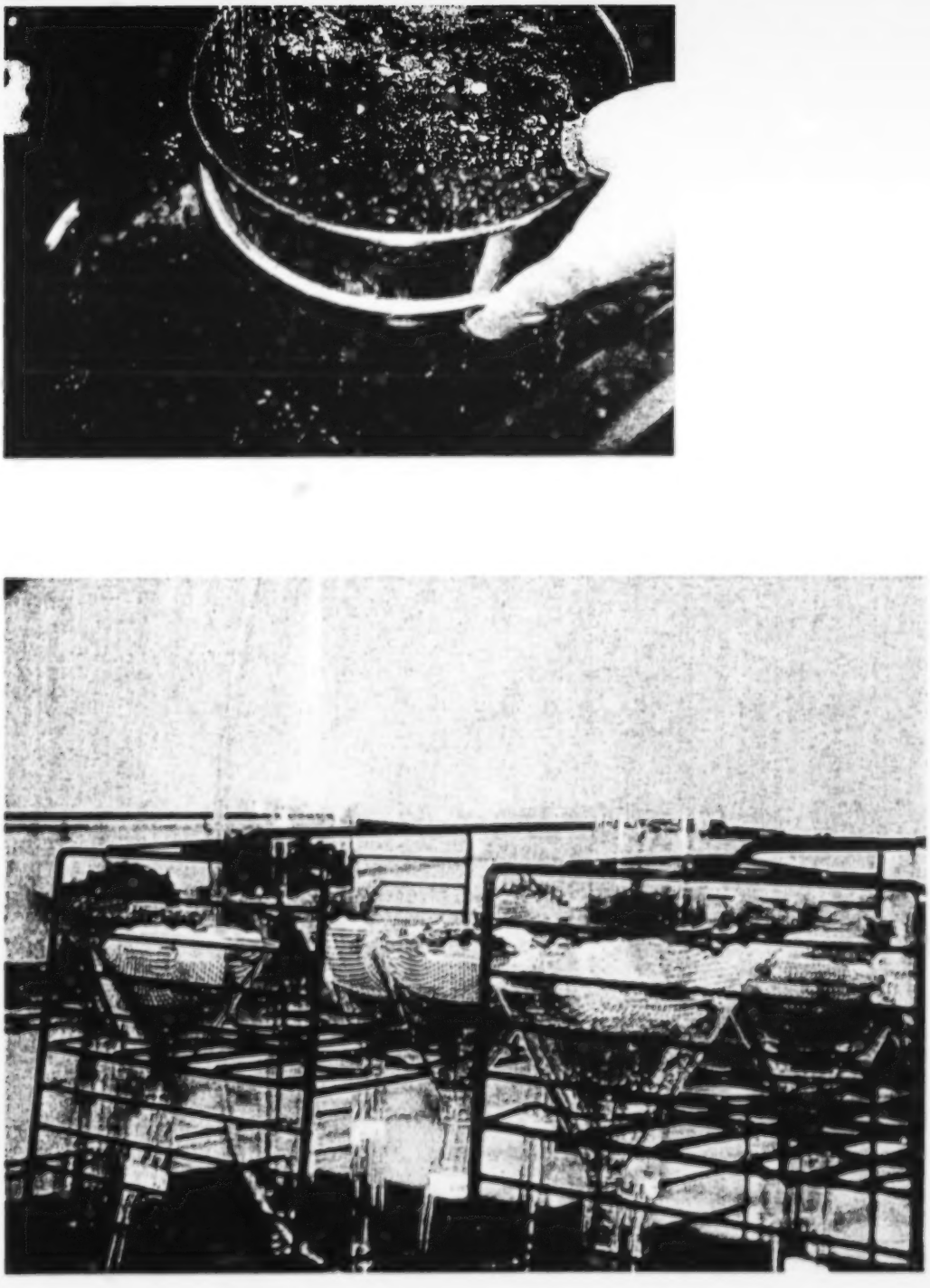


Fig. 5. Upper: sieving of soil for root preparation. Lower: roots and crowns in funnels on filter paper and screens for nematode sampling.

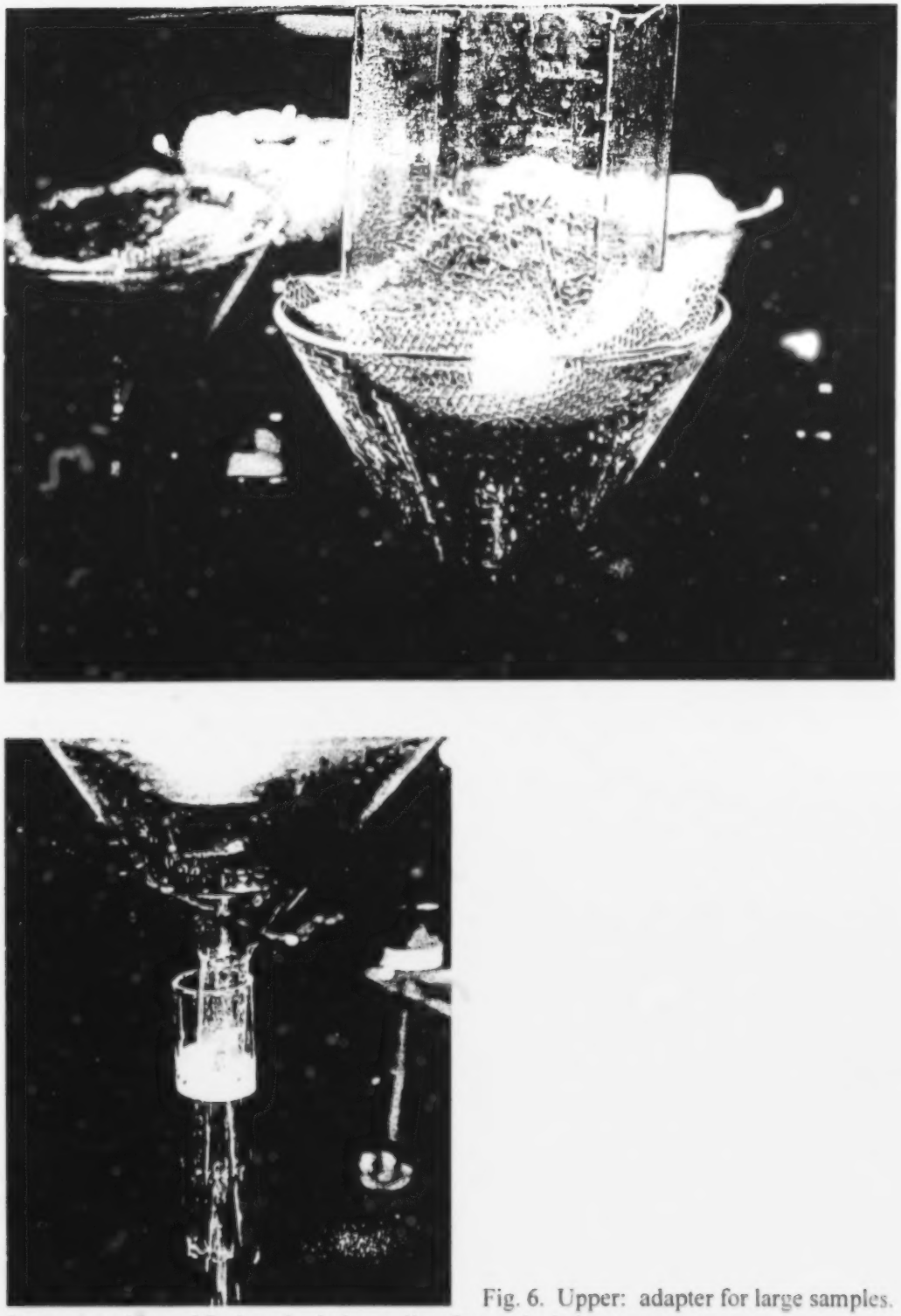
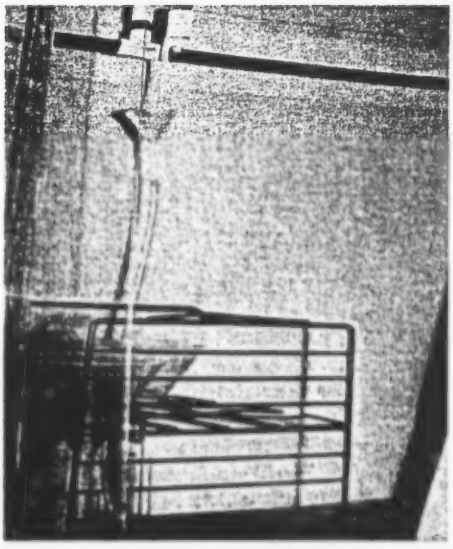


Fig. 6. Upper: adapter for large samples. Lower: position of flask end relative to lip of test tube is important.



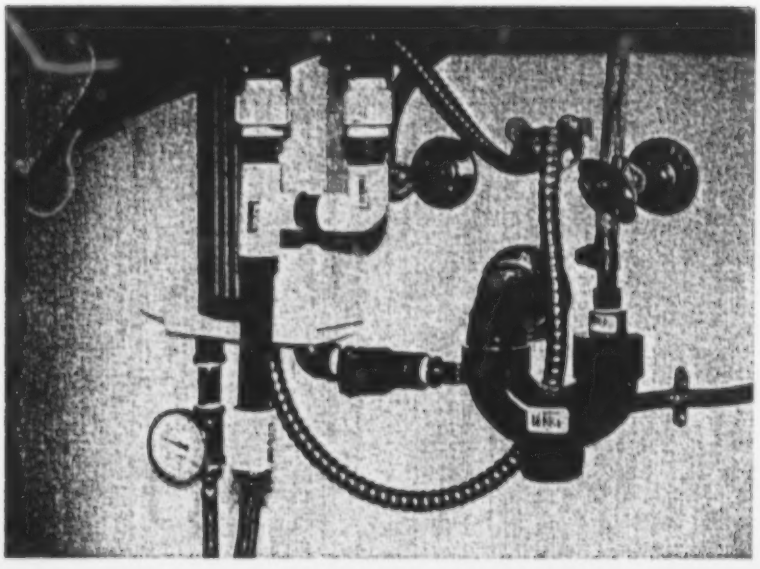
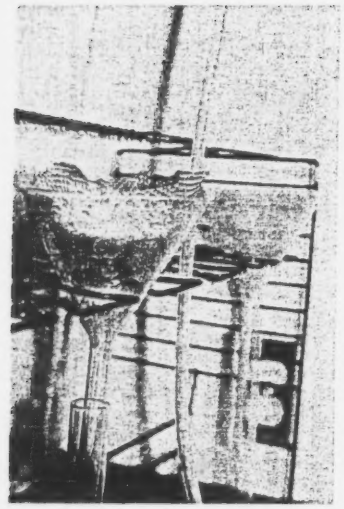


Fig. 7. Upper: Funnel to catch initial water. Lower: Temperature of water is important: should not be cold (kills nematodes) and should be around 23°C. Heater was placed on the plumbing system to heat the deionized water.



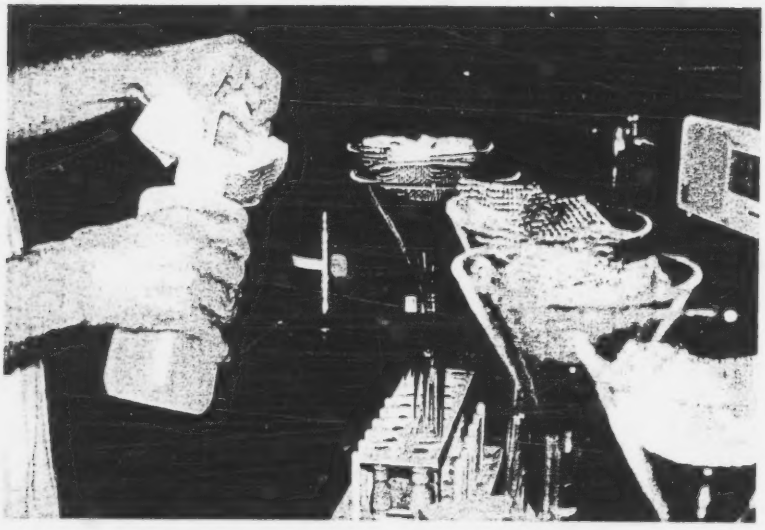
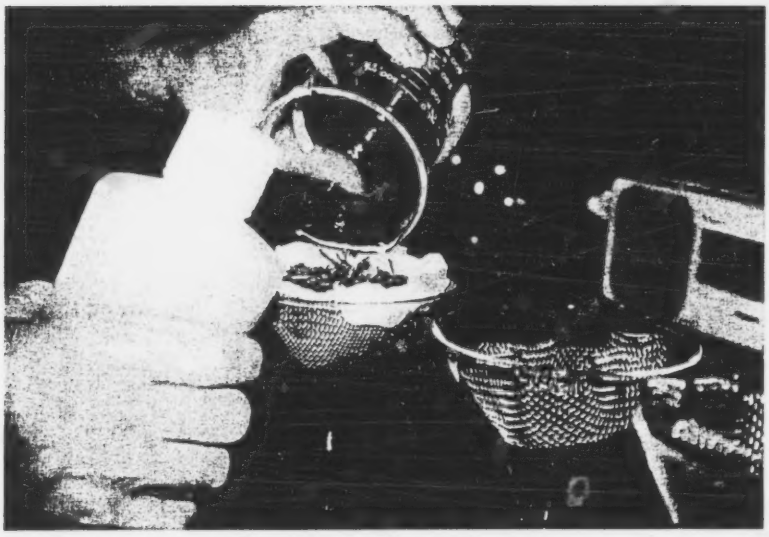


Fig. 8. Pre-wetting the filter papers prior to placement on the mesh screen.



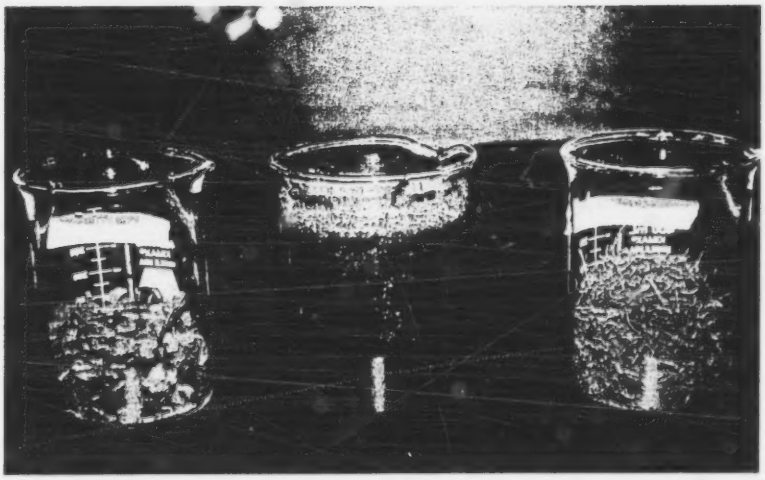


Fig. 9. Lower: strawberry crowns (left), root tissue (center), cattail sample (right) before nematode extraction by placing onto moist filter paper and mesh screen.